
विधुत ऊर्जा संग्रहण प्रणालियाँ:
सुरक्षा अपेक्षाएं

**Electrical Energy Storage Systems:
Safety Requirements**

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft, finalized by Energy Storage Systems Sectional Committee had been approved by the Electrotechnical Division Council.

This standard provides guidance to the industry and manufacturers of storage systems regarding the safety requirements of Electrical Energy Storage (EES) Systems. The manufacture and use of storage systems is on the increase in the country and hence the need for formulation of Indian Standard has been realized.

Considerable assistance has been obtained from UL-9540 : 2016 in preparation of this standard. This standard corresponds to the requirements of UL-9540 : 2016, but certain modifications has been made in relation to the cross referred standards, included content therefrom, and ambient conditions were also modified.

Certain articles are also taken from IEC 62933-5-1 : 2017, for example, Hazard considerations for EES Systems, Cyber Security, etc.

The standards provided in Annex B of this standard are for information only.

*Indian Standard***ELECTRICAL ENERGY STORAGE SYSTEMS:
SAFETY REQUIREMENTS****1 SCOPE**

1.1 This standard covers the safety requirements of Electrical Energy Storage (EES) systems that are intended to receive electric energy and then to store the electrical energy so that the energy storage system can provide electrical energy to loads or to the local/area Electric Power System (EPS) up to the utility grid when needed. The types of energy storage covered under this standard include electrochemical, chemical, mechanical and thermal. The energy storage systems equipment (constructed either as one unitary complete system or as matched assemblies that when connected are the system) may include equipment for charging, discharging, control, protection, power conversion, communication, controlling the system environment, air, fire detection and suppression system, fuel or other fluid movement and containment, etc. The system may contain other ancillary equipment related to the functioning of the energy storage system.

1.2 The systems covered by this standard include those intended to be used in a standalone mode (for example, islanded) including ‘self-supply’ systems to provide electric energy and those used in parallel with an electric power system or electric utility grid such as ‘grid-supply’ systems, or applications that perform multiple operational modes.

1.3 Requirements for installation and transportation, with the exception of installation manuals and documents for installation provided with the system that are integral to the tested system are outside the scope of this standard. The installation instructions indicate that the electrical energy storage systems are to be installed in accordance with the national and local electrical codes and other applicable codes. This standard assumes that the final installation of the energy storage system will be performed by qualified service personnel in accordance with the applicable installation instructions, installation practices and Indian installation codes. Energy storage systems are intended for installation subject to approval by the concerned regulator. Compliance to all the relevant statutory requirements, rules and regulations would be as applicable.

NOTE — Units of Measurement: Values and their respective units of measurement that are stated without parentheses constitute the requirement of the standard and those in parentheses constitute explanatory or approximate information.

2 REFERENCES

The Standards provided in Annex A contain provisions which through reference in this text, constitute provisions of the standards. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the Standards indicated in Annex A.

3 GLOSSARY

For the purpose of this standard, the following definitions shall apply.

3.1 Electric Power System (EPS) — Electric Power System means all aspects of generation, transmission, distribution and supply of electricity and includes one or more of the following, namely:

- a) generating stations;
- b) transmission or main transmission lines;
- c) sub-stations;
- d) tie-lines;
- e) load despatch activities;
- f) mains or distribution mains;
- g) electric supply-lines;
- h) overhead lines;
- j) service lines; and
- k) works.

3.2 Energy Storage (ES) System — Equipment that receives electrical energy and then provides a means to store that energy in some form for later use in order to supply electrical energy when needed. EES are classified into mechanical, electrochemical, chemical, electrical and thermal energy storage systems, as shown in Fig. 1.

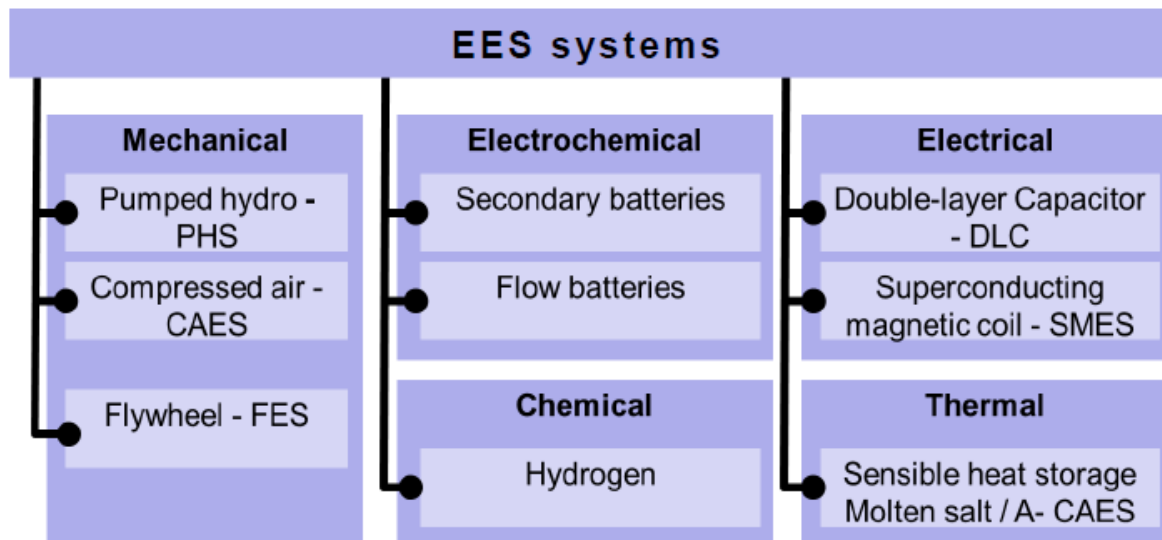


FIG. 1 EXAMPLE OF CLASSIFICATION OF EES SYSTEMS

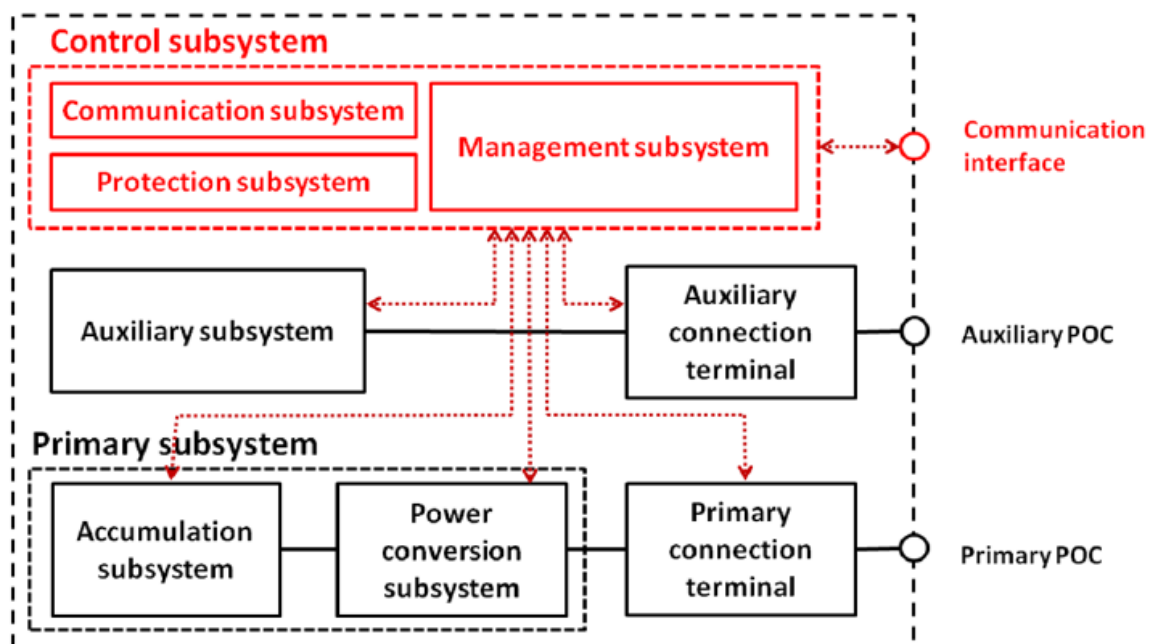


FIG. 2 EES SYSTEM ARCHITECTURE WITH TWO POC TYPES

- a) **Electrochemical energy storage system** — Consists of a secondary (rechargeable) battery electrochemical capacitor, flow battery or hybrid battery-capacitor system that stores electrical energy and any associated controls or devices that can provide the stored electric energy upon demand.
- b) **Chemical energy storage system** — Consists of hydrogen storage, the hydrogen generator to supply the hydrogen for storage, and a fuel cell power system to provide electric energy upon demand.
- c) **Mechanical energy storage system** — Consists of a mechanical means to store energy such as through compressed air, pumped water or fly wheel technologies and associated controls and systems, which can be used to run an electric generator to provide electric energy upon demand.
- d) **Thermal energy storage system** — Consists of a system that uses heated fluids such as air as a means to store energy along with associated controls and systems, which can be used to run an electric generator to provide electrical energy upon demand.

Examples:

Technology	Input Energy Conversion Mechanism	Energy Storage Mechanism	Output of Energy Storage Mechanism
Electrochemical	Charger	Battery system	Converter
Chemical	Water electrolysis hydrogen generator	Hydrogen storage	Combustion generator fuel cell
Mechanical	Air compressor, Pumped Storage	Flywheel, upper reservoir	Motor generator
Thermal	Heat pump	Thermal storage	Heat generator or heat exchanger.

There can be two different EES Architectures as shown in Fig. 2 and Fig. 3.

The terms and definitions explaining the block diagram of the two architectures of Electrical Energy Storage Systems (EESs), as shown in Fig. 2 and Fig. 3.

3.3.1 Point of Connection (POC) — Reference point on the electric power system where an EES system is connected.

NOTE— An EES system may have several POCs in two different classes: primary POC and auxiliary POC. From an auxiliary POC, it is not possible to charge electrical energy, in order to store internally and, finally, discharge to the electric power system, but a primary POC can be used to feed the auxiliary subsystem and the control subsystem. In absence of an auxiliary POC, the primary POC can be named simply as POC.

3.3.2 Primary POC — Point of connection where the EES system charges electrical energy from the electric power system, in order to store it internally and, finally, discharge it to the electric power system.

NOTE — Generally, the primary POC is connected with the EES system primary subsystem through the primary connection terminal.

3.3.3 Auxiliary POC — EES system point of connection with the electric power system used to feed the auxiliary subsystem and, so, the control subsystem, respectively, only if primary POC is not used to feed each subsystem.

NOTE — Generally, an auxiliary POC can be replaced with another source of electrical energy (for example, a diesel generator).

3.3.4 Connection Terminal — Component of an EES system used for the connection to a POC.

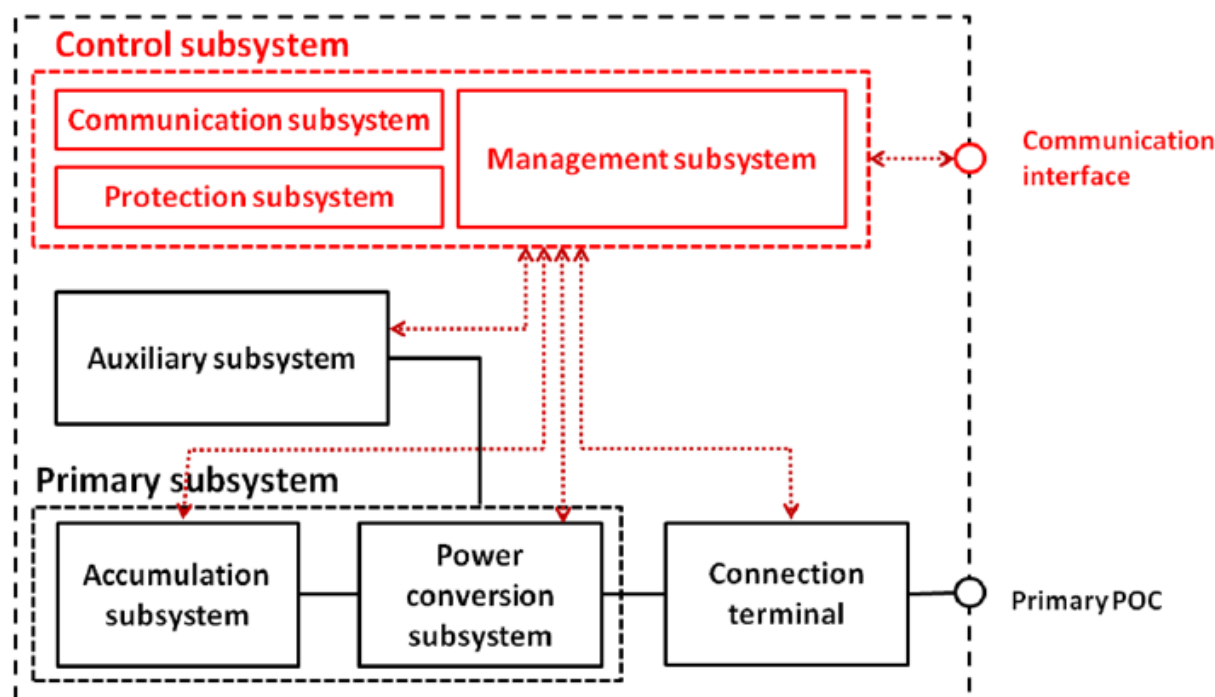


FIG. 3 EES SYSTEM ARCHITECTURE WITH ONE POC TYPE

NOTE— An EES system may have several connection terminals in two different classes: primary connection terminals and auxiliary connection terminals. In absence of an auxiliary POC, the primary connection terminal can be named simply as connection terminal.

3.3.5 Primary Subsystem — EESS subsystem consisting of the components/subsystems that are directly responsible for storing electrical energy and extracting electrical energy.

NOTE — Generally, the primary subsystem is connected to the primary POC and comprises at least the accumulation subsystem and the power conversion subsystem.

3.3.6 Accumulation Subsystem/Storage Subsystem — EESS subsystem, comprising at least one EES, where the energy is stored in some form.

NOTES:

1 Mechanical energy, electrochemical energy, electromagnetic energy are frequent forms of stored energy.

2 Generally, the accumulation subsystem is connected to the power conversion subsystem that performs the necessary power conversion to electrical energy; however, in some cases, a power conversion is embedded in the accumulation subsystem (for example, in electrochemical secondary cells the energy is directly available in the electrical form).

3.3.7 Power Conversion Subsystem — EESS subsystem where energy is converted from the available form at the output of the accumulation subsystem of the EES system to electrical energy.

NOTE — Generally, the power conversion subsystem is connected to the accumulation subsystem and to the primary POC through the primary connection terminal.

3.3.8 Auxiliary Subsystem — EESS subsystem containing equipment intended to perform particular functions additional to storing/extracting electrical energy which is done in the primary subsystem.

NOTES:

1 Generally, the auxiliary subsystem is connected to the auxiliary POC through the auxiliary connection terminal.

2 The equipment of the auxiliary subsystem (auxiliary equipment) are normally indispensable for setting up all the EESS operational states and assessing the correct performance (operation) of the primary and control subsystems during any operating mode.

3 Auxiliary subsystem can be configured to take the energy from primary subsystem.

3.3.9 Control Subsystem — EES subsystem serving for monitoring and controlling the EES, by including all equipment and functions for acquisition, processing, transmission, and display of the necessary process information.

NOTES:

1 Generally, the control subsystem may be connected to the communication interface and it comprises at least the management subsystem, the communication subsystem and the protection subsystem.

2 Control subsystem is normally fed by the auxiliary subsystem.

3.3.10 Communication Subsystem — EES subsystem containing an arrangement of hardware, software, and propagation media to allow the transfer of messages from one EES component/subsystem to another one, including the data interface with external links.

3.3.11 Management Subsystem — EES subsystem providing the functionality needed for the safe, effective and efficient EES system operation.

3.3.12 Protection Subsystem — EES subsystem containing an arrangement of one or more protection equipment, and other devices intended to perform one or more specified protection functions.

NOTES:

1 The protection subsystem includes one or more protection equipment, instrument transformer(s), transducers, wiring, tripping circuit (s), and auxiliary supply. Depending upon the principle(s) of the protection subsystem, it may include one end or all ends of the protected section and, possibly, automatic reclosing equipment.

2 The switches and fuses are excluded.

3.4 Arc Flash Boundary — The area within which a hazardous arc could occur, and which requires the use of Special Protective Equipment (SPE).

3.5 DUT — Device under test.

3.6 Electric Energy Storage System Integrator — The entity typically responsible for ensuring the various parts of the energy storage system work together, and that the energy storage system works with the external systems that either supply energy into the energy storage system or use energy from the energy storage system.

3.7 Enclosure — The outer cover of the Energy Storage System that provides protection to its contents.

3.8 Failure Modes and Effect Analysis (FMEA) — A rigorous and systematic methodology for analyzing reliability and impact, the failure of any one component associated with the technology and its installation, has on safety. For the purposes of this standard, only the impact to safety is considered. The reference for conducting FMEA study shall be provided as per IEC 60812.

3.9 Fuel Cell Power System — Equipment that converts chemical energy in the form of a fuel and oxidant into electrical energy with heat and by-products from the reaction.

3.10 Hazardous Arc — An electrical arc with sufficient energy to result in physical hazards to someone coming in contact with it.

3.11 Hazardous Fluid — A hazardous material (for example, toxic, combustible, etc.) that is either a liquid or a gas.

3.12 Hazardous Voltage — Voltage exceeding $30 V_{rms}$ /42.4 V AC peak or $60 V_{DC}$ is considered hazardous.

3.13 Insulation Levels — The following are levels of electrical insulation:

- Basic insulation — A single level of insulation that is intended to provide protection against electric shock when the insulation has not failed.
- Double insulation — Insulation comprising both basic insulation and supplementary insulation.
- Functional insulation — Insulation that is necessary only for the correct functioning of the equipment that can reduce the likelihood of ignition and fire, and that does not protect against electric shock.
- Reinforced insulation — Single insulation system that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard. The term ‘insulation system’ does not imply that the insulation has to be in one homogeneous piece. It may comprise several layers that cannot be tested as basic insulation and supplementary insulation.
- Supplementary insulation — Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

3.14 Non-Combustible Dielectric Medium — A transformer fluid that does not ignite, burn, give off flammable vapors or support combustion in air.

3.15 Restricted Access Location — Location for energy storage system equipment as identified in the installation manual and equipment markings, or as required by local codes, where both of the following apply:

- Access can only be gained by service persons or by users who have been instructed about the reasons for the restrictions applied to the location, the hazards present at the location, and about any precautions that shall be taken; and
- Access is through the use of a tool or lock and key, or other means of security, and is controlled by the authority responsible for the location.

3.16 Ambient Temperature — Considered to be a temperature in the range of $35 \pm 5^\circ\text{C}$.

3.17 Safety Critical Circuits/Components — Those circuits or components that are relied upon for critical safety (that is, mitigating a potential hazard to persons) as identified in the safety analysis of 14.2.

3.18 Safety Extra Low Voltage (SELV) Circuit — A circuit that exhibits voltages that are not in excess of those in Table 1 and are safe to touch both under normal operating conditions and after a single fault. Another

term used for similar circuits is Protective Extra Low Voltage (PELV).

Table 1 SELV Voltage Limits

(Clause 3.18)

Voltage Limits	
Normal	Single Fault
Open circuit voltage with generally sinusoidal shape of 42.4 V _{peak} /30 V _{rms} or 60 VDC	Open circuit voltage with generally sinusoidal shape of 42.4 V _{peak} /30 V _{rms} or 60 VDC with excursions up to 71 V _{peak} /50 V _{rms} or 120 VDC for periods up to 200 ms

3.19 Special Purpose Utility-Interactive (Inverter / Converter / Product) — An inverter / converter / product that is functionally similar to a utility-interactive inverter except that it is evaluated for specific applications different from those where utility-interactive inverters are generally used. These units may have specific utility interconnection protection settings that allow them to provide grid support and operate during abnormal grid events such as low voltage ride through (LVRT). These products may rely upon internal or external utility interconnection protection functions or devices, as identified for the particular product. External utility interconnection protection may be provided by means of utility protection relays as required by the local electric utility.

3.20 Utility-Interactive (Inverter) — An inverter intended for use in parallel with an electric utility to supply common loads and sometimes deliver power to the utility.

3.21 Hazard — Potential source of harm.

3.22 Hazardous Substance — Hazardous material substance which can affect human health or the environment with an immediate or retarded effect or is capable of posing an unacceptable risk to health, safety, property or to the environment.

3.23 Fire Hazard — Condition of an EES system with a potential for an undesirable consequence from fire.

3.24 Explosion Hazard — Condition of an EES system with a potential for an undesirable consequence from explosion.

3.25 Mechanical Hazard — Condition of an EES system with a potential for an undesirable consequence from physical force.

3.26 Thermal Hazard — Condition of an EES system with a potential for an undesirable consequence from thermal effect.

3.27 Utility-Interactive Inverter/Converter, Grid Support — An inverter or converter intended for

use in parallel with an electric utility, that is, a Utility Interactive inverter that is additionally evaluated for specific grid support functions different from those as defined in the IEEE 1547 and UL 1741. Inverter or converter applicable for solar power system shall conform to IS 16221. These units have specific utility interconnection settings that allow them to provide grid support functionality such as voltage and frequency regulation functions and voltage and frequency ride through.

4 HAZARD CONSIDERATIONS FOR EES SYSTEMS

4.1 Electrical Hazards

Electricity travels in closed circuits, normally through a conductor. But sometimes a human body and, when proximate, water and even air can be conductors of electricity and inadvertently become part of the electric circuit. Electrically caused pain or injury (electric shock) may occur when electrical energy capable of causing pain or injury is transferred to a body part.

Electrical energy transfer occurs when there are two or more electrical contacts to the body:

- a) Between a body part and a conductive part of the equipment; and
- b) Between another body part and earth and water or another conductive part of the equipment.

When a person receives a shock, electricity flows between parts of the body or through the body to the ground or the earth. Depending on the magnitude, duration, wave shape, and frequency of the current, the effect to the human body varies from undetectable to detectable to painful to injurious. Burns are the most common shock-related injury but electric shock may also cause ventricular fibrillation. In addition to shock and burn hazards, electricity poses other dangers. For example, arcs that result from short circuits during work on energized systems, referred to as 'arc flash', can cause injury or start a fire. Thermal burns can also be caused when clothing catches fire, as may occur when an electric arc is produced. Arc flash boundaries should be determined to establish appropriate levels of personal protective equipment for workers involved in maintenance and other actions on energized equipment. Extremely high-energy arcs can damage equipment, causing fragmented metal to fly in all directions. Even low-energy arcs can cause violent explosions in atmospheres that contain flammable gases, vapors, or combustible dusts. Static electricity can also cause shocks or can just discharge to an object with serious consequences, as friction causes a high level of static electricity to build up at a specific spot on an object. This can happen simply through handling plastic pipes and materials or during normal operation of rubberized drives or machine belts found in many worksites. In these cases, for example, static electricity

can potentially discharge when sufficient amounts of flammable or combustible substances are located nearby and can cause an explosion.

Electric hazards can also arise from inappropriate electric firefighting procedures.

4.2 Mechanical Hazards

Mechanically caused injury is due to kinetic energy transfer to a body part when a collision occurs between a body part and an equipment part. The kinetic energy is a function of the relative motion between a body part and accessible parts of the equipment, including parts ejected from the equipment that collide with a body part.

Examples of kinetic energy sources are:

- a) Body motion relative to sharp edges and corners;
- b) Part motion due to rotating or other moving parts, including pinch points;
- c) Part motion due to loosening, exploding, or imploding parts;
- d) Equipment motion due to instability;
- e) Equipment motion due to wall, ceiling, or rack mounting means failure;
- f) Equipment motion due to handling failure;
- g) Part motion due to an exploding battery;
- h) Equipment motion due to cart or stand instability or failure;
- j) Displacement due to mechanical vibration; and
- k) Equipment motion due to interaction with natural risks (flood, earthquake, etc.).

Mechanical trauma includes friction, pressure, abrasions, lacerations and contusions causing more or less serious injuries.

4.3 Explosion Hazards

An explosion is a rapid expansion of gases resulting in a rapidly moving pressure or shockwave. Explosions are classified according to the nature of the system 'transformation', and usually explosions of physical origin and chemical origin are distinguished. Physical explosions include BLEVE (Boiling Liquid Expanding Vapor Explosion) which is a violent explosive vaporization leading to the rupture of a tank containing a liquid at a temperature significantly above its normal boiling point at atmospheric pressure. In this case the 'transformation' is a variation of internal energy.

Chemical explosion can result from the runaway of exothermic chemical reaction or from the decomposition of unstable substances. The burning of a fuel/air mixture's combustible vapors (gas explosions) and burning of a suspension's air/fuel particles (dust explosions) are also involved, and the transformation is a combustion reaction of an explosive atmosphere. The potential hazards associated with explosive atmosphere

are released when ignited by an effective ignition source.

In general explosions of solids, liquids or gases are divided into two types:

- a) Deflagrations, and
- b) Detonations.

In both types a reaction zone propagates through the reactant(s). Owing to the density difference, the energy release per unit of volume is much higher for liquids and solids than for gaseous reactants. Explosions endanger the lives and health of those exposed as a result of the uncontrolled effects of flame and pressure, the presence of noxious reaction products, the discharge of projectiles, and the consumption of the oxygen in the ambient air.

4.4 Hazards Arising From Electrical, Magnetic, and Electromagnetic Fields

In addition to the conventional electrical hazards high-level electromagnetic energy produced by Radio Frequency Radiation (RFR) can also induce electrical currents or voltages that may be a source of disturbance on other equipment, cause electrical arcs that may ignite flammable materials, or act as an ignition source in explosive atmospheres' hazardous areas. IEC 61000 may be referred for Electromagnetic Compatibility (EMC) related issues.

4.5 Temperature Hazards

Thermal energy transfer occurs when a body touches a hot equipment part or hot liquids. The extent of injury depends on the temperature difference, the thermal mass of the object, rate of thermal energy transfer to the skin, and duration of contact. The perception of the human body varies from warmth to heat that may result in pain or injury (burn). Hot smoke inhalation can cause burn injury. In fact, 60 percent to 80 percent of burn fatalities come from major smoke inhalation. The immediate effects can include fainting, blockages of airways, singed facial and/or nose hair, and burns around the face and neck. Smoke inhalation can also lead to pulmonary (lung) injury. Exposure to thermal radiation can cause burns to the skin. The radiation types of greatest concern are thermal radiation issued from open flames and explosions. Exposure to extreme cold temperatures could also generate some injury to skin and body parts. Normal operations as well as abuse conditions can both generate dissipation of heat and therefore potential thermal hazards

4.6 Chemical Hazards

Injury caused by hazardous substances is due to a chemical reaction with a body part. The extent of injury by a given substance depends on both the magnitude and duration of exposure and on the body part's susceptibility to that substance. A worker's skin and eyes may be exposed to hazardous chemicals through

direct contact with contaminated surfaces, deposition of aerosols, immersion, or splashes.

Chemical agents are divided into two types: primary irritants and sensitizers. Primary or direct irritants act directly on the skin through chemical reactions. Sensitizers may not cause immediate skin reactions, but repeated exposure can result in allergic reactions. Contact with strong acids or alkaloids or other corrosive or caustic materials can eat away or 'burn' skin and deeper tissue. These can be caused by various chemicals used in workplaces. There are also the immediate and long-term dangers from inhaling, swallowing or absorbing toxic chemicals through the skin.

Chemical effect may be fire induced (for example, fire gases toxicity) or not (release of effluents during normal operations) or may be induced through heating chemicals beyond decomposition temperature in either normal or abuse conditions. Chemical effect may also encompass creating an explosive atmosphere by production of flammable gases (for example, hydrogen). Discharge of previously accumulated toxic gas can generate serious hazards in terms of massive exposure to humans in the area. In addition, leaching in to soil and severe corrosion issues may be triggered.

4.7 Fire Hazards

A fire hazard occurs if combustible materials, oxidizer and ignition energy are available in sufficient quantities at the same place and at the same time. The fire hazard depends on the interaction of these three items. Certain materials are inherently unstable, or have extraordinary oxidizing properties, or are capable of self-heating. This affects the fire hazard.

Variation in the oxygen concentration (for example, oxygen enrichment) can also significantly affect the fire hazard. The fire hazard can arise from the materials used or released by the EES system, from materials in the vicinity of the EES system, or from materials used in the construction of the EES system. Combustible materials can occur as solids, liquids or gases of organic or inorganic nature. It should be determined whether combustible materials exist or can exist and in what quantity and distribution.

The ease of combustion of materials is affected by the size, shape and deposition of the materials. For example, small pieces of a material loosely collected together can be more easily ignited than a large piece of that material. The combination of materials can also have an influence on the ignitability and the burning behavior. Consideration should be given as to whether the properties of the materials can change over time or with use. Such changes can include the possibility of decomposition of the material releasing combustible gases and vapors. This can lead to an increased fire hazard.

In assessing the fire hazard, the existence and quantity of fire supporting substances, for example oxygen

producing substances, and the probability of their occurrence should be determined. The most common oxidizer is air but there are other oxidizers which support combustion, for example, potassium nitrate (KNO_3), potassium permanganate (KMnO_4), per chloric acid (HClO_4), hydrogen peroxide (H_2O_2), and nitrous oxide (N_2O).

It should be determined which ignition sources exist or can occur. Possible ignition sources can arise due to the influence of:

- a) Heat energy;
- b) Electrical energy;
- c) Mechanical energy; and
- d) Chemical energy.

Electrically caused fire is due to conversion of electrical energy to thermal energy where the thermal energy heats a fuel material followed by ignition and combustion. Electrical energy is converted to thermal energy either in a resistance or in an arc and is transferred to a fuel material. Fire initiation is produced when sufficient energy release allows the heating of a fuel element by conduction, convection, or thermal radiation to a temperature such that a combustion reaction starts. It should be noted that the combustion reaction will always occur between the oxygen and the gaseous fuel.

Depending on the nature of the fuel (gas, liquid or solid), the ignition process will be different. For gases, the initiation occurs in a fuel oxidizer mixture with proportions between the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL). The energy input to initiate combustion mixture is often very low. This energy is commonly measured in the stoichiometric proportions of the combustion reaction. Hence, it is called Low Energy Flammability (LEF). This energy is often of the order of a few milli Joules. A spark may be enough to ignite the mixture. For liquids, combustion occurs from the vapor emitted, provided that the vapor emission rate is sufficient to create a flammable mixture with the ambient air. In addition, ignition of the mixture will only occur if enough energy ($\geq$ LEF) is provided when the temperature of the liquid is higher than its temperature flash point. For solid fuels, the initiation phenomenon is more complex because it is governed by heat transfer within the material. The energy received by the fuel increase the temperature of the solid until the sublimation or decomposition temperature is reached. This process is called the pyrolysis phenomenon. The initiation time depends on the intensity of the thermal flow, of the thermal properties, of the ignition temperature and of the water content. The propagation phase corresponds to the rise of fire related to the path of combustion of the flammable items. During this phase the position of the fuel elements plays an important role as a criterion that enables or impedes the development of the fire. The fire hazard can result for example from the fire itself,

the thermal radiation, the fire effluent, or the escaping materials. An explosion hazard may exist in addition to the fire hazard. Thermal and chemical fire-induced hazards threaten people and the environment. These fires may vary highly in nature and intensity according to the material that is burning (nature, geometry, and quantity) and burning conditions.

5 CYBER SECURITY

Cyber security is important not only for remote monitoring but also for the system connected to the internet. Refer to international standards for additional guidance.

6 CONSTRUCTION- NON-METALLIC MATERIALS

6.1 Polymeric materials employed for enclosures of electrical equipment shall comply with **6.2** and the enclosure requirements as given in UL 746C, Path III.

6.2 In addition to the items in **6.3**, polymeric electrical enclosures shall have the following properties:

- a) Minimum 5 VA flame rating, or the enclosure complies with the 127 mm Flame test of UL 746C, and may require flame spread testing per the Enclosure Flammability - Large Surface Area Considerations test of UL 746C;
- b) Insulation material properties as per the Material Property Considerations table of UL 746C;
- c) Compliance with the Strain-Relief Test after Mold Stress-Relief Distortion of UL 746C if serving as a securement means for a strain relief;
- d) Compliance with the Ultraviolet Light Exposure test of UL 746C if exposed to UV rays in the end use;
- e) Compliance with the Water Exposure and Immersion test of UL 746C if exposed to rain in the end use; and
- f) Compliance with the Conduit Connections in the Enclosure Requirements table of UL 746C if mounting conduit connections.

6.3 The following factors from (a) to (e) are taken into consideration when an enclosure employing nonmetallic materials is being examined. For a nonmetallic enclosure, all of these factors are to be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is ensured by compliance to the mold stress relief test. Compliance with factors (a) to (e) as follows may be determined by the tests of this standard or by UL 746C or UL 1973:

- a) Resistance to impact;
- b) Crush resistance;
- c) Abnormal operations;

- d) Severe conditions; and
- e) Mold-stress relief distortion.

6.4 Materials employed as electrical insulation in the system shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. Insulation materials that are in direct contact with or close proximity to hazardous live parts in accordance with Fig. 1 of UL 746C, shall additionally meet the insulation criteria outlined in standard unless employed as part of a component that has been evaluated to a component standard that has comparable safety criteria. Insulated wiring is subjected to the requirements outlined in 10.

6.5 Gaskets and Seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.

7 METALLIC PARTS RESISTANCE TO CORROSION

Metallic enclosures shall be corrosion resistant to prevent deterioration that would affect the ability of the enclosure to provide physical protection to EES System components or access to hazardous parts that could result in a hazardous condition. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection is given in ISO 12944-2. The enclosure material selection shall be based on IS 14321.

8 ENCLOSURES AND GUARDING OF HAZARDOUS PARTS

8.1 The enclosure (s) of an Energy storage system shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its transportation, installation and intended use.

8.2 Openings in the enclosure of an electric energy storage system shall be designed to prevent inadvertent access to hazardous parts. Compliance shall be determined in accordance with clause 12 of IS/IEC 60529.

Exception — An electrical energy storage system intended for restricted access locations need not meet the accessibility criterion if permanent warning markings for service and other personnel having access to the system are provided directly on the system. Protection from access to live parts in restricted locations shall be in accordance with SP 30, Suitable cautionary warnings and signage for identifying exposed hazardous voltage circuits shall be provided for protection of service personnel.

8.3 In service access areas, bare parts of hazardous voltage circuits, shall be located or guarded so that

accidental shorting across circuits at opposite polarity, or to ground, or to SELV circuits or communications circuits, that could be caused by items such as, but not limited to, tools or test probes used by service personnel, is unlikely. Parts in class 2 or limited power circuits need not be located or guarded from accidental contact by service personnel.

8.4 Enclosures of systems and components of systems located where they will be subject to exposure to water and other elements shall be rated for the level of intended exposure. Installation instructions shall indicate restrictions with regard to limiting ingress from the environment based upon the enclosure rating.

9 GENERAL ELECTRICAL SAFETY AND WALK-IN SYSTEMS

9.1 The instructions shall include measures and procedures for worker safety in, on or adjacent to the energy storage system according to the SP 30.

9.2 Where persons can access the hazardous areas within the energy storage system enclosure, procedures for safe entry into and exiting the system shall be provided in the product's instructions. Means, such as but not limited to a placard (s) and lock (s), shall be provided to prevent unauthorized persons from entering these hazardous areas.

9.3 Entrances to the enclosure shall be designed to prevent persons from becoming trapped within the enclosure (that is, entrances shall be able to be opened from inside the enclosure without use of a tool or key should they become closed). Personnel door (s) intended for entrance to, and egress from an enclosure, shall open in the direction of egress. The egress door shall be marked with the word 'Exit' and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked 'Not an Exit' or with an indication of its actual use.

9.4 Work space dimensions and requirements within an energy storage system, including walk-in enclosures, shall be in accordance with SP 30. The space requirement shall also provide for appropriate arc flash safety under specified Personal Protective Equipment (PPE).

9.5 Areas of access to walk in enclosures of energy storage systems shall be designed to prevent tripping, slipping or falling when persons enter, exit or while within the system enclosure. Surfaces and parts within a walk in energy storage system enclosure shall be designed to prevent inadvertent hazards to personnel within the enclosure through appropriate guarding, electrical and thermal insulation methods and cautionary warnings and signage in accordance with this standard.

9.6 Protection against contact with hazardous voltage parts in the energy storage system including walk-in enclosures shall be in accordance with **8.2** or through the use of guarding to prevent access with cautionary warnings and signage where only qualified personnel are allowed access. Entrances to walk-in enclosures that contain exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter. *See also 11.2* with regard to disconnect criteria for servicing, etc.

9.7 The type of protection equipment to be provided for arc flash hazards shall be determined by an arc flash risk assessment conducted according to SP 30. The assessment shall determine:

- a) The arc flash incidental energy level;
- b) The restricted approach boundary; and
- c) The required arc flash personal protective equipment.

9.8 An arc that can create a second degree burn to unprotected skin and therefore considered the level for determining an unprotected arc flash boundary, has an arc rating above 5 J/cm² incident energy level.

9.9 Energy storage system enclosures that can be fully entered by persons shall have adequate ventilation for persons working within the enclosure. The amount of airflow determined adequate is based upon the floor area of the energy storage system and the maximum number of persons that can enter the walk-in enclosure at one time in accordance with SP 7. ASHRAE 62.1 provides a formula for calculating this based upon different types of occupancies. As guidance for determining suitable airflow in a normally unoccupied energy storage system enclosure, the values for a storage space of dry goods may be used as a close approximation for estimating airflow in an area that is not routinely occupied, and using Table 6.2.2.1 of ASHRAE 62.1 for values. If the number of persons to occupy the space is not known, it is recommended to use 2 persons/100 m² as a default amount.

9.10 Electrical circuits that are an integral part of the energy storage system including those that are part of a walk-in enclosure including lighting, controls, power, HVAC (heating, ventilation and air-conditioning), emergency lighting, alarm circuits, and the like shall comply with the appropriate requirements for the type of equipment and the specific application within the energy storage system.

9.11 Electrical equipment including electrical equipment that is located in the walk-in enclosure in areas that will be subject to condensation, or the effects of condensation from equipment or systems that are provided with and installed in, on or around the energy storage system enclosure, shall be suitable for outdoor use or suitably protected against contact with water

and protected against unsafe conduction of hazardous voltages to personnel via water as a conduction path.

9.12 Lighting shall be provided in enclosed working spaces. Lighting must be adequate and lighting outlets shall not be controlled by automatic means. Additional lighting outlets shall not be required where the work space is illuminated by an adjacent light source. Lighting within an energy storage system including lighting within a walk-in enclosure shall be installed in accordance with SP 30.

9.13 Where there is more than one source of supply energizing the energy storage system, the energy storage system shall be provided with information and markings to indicate which disconnect device or devices are required to be operated to completely isolate the equipment.

9.14 Protection against lightning surges shall be provided in accordance with the requirements of the SP 30.

10 WIRING AND ELECTRICAL SUPPLY CONNECTIONS

10.1 Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment or when supplied with the equipment and intended for installation exterior to the equipment.

10.2 Wiring methods and electrical supply connections of the energy storage system shall be in accordance with the SP 30.

10.3 An energy storage system or component of the energy storage system shall have provision for connection of the system to an external wiring system consisting of:

- a) Wiring terminals or wiring leads; or
- b) A means for connection of cable or conduit in accordance with the codes in **10.2**.

10.4 A wiring terminal or lead that is supplied as a component of the energy storage system shall be rated and sized for connection to a field wiring conductor having an ampacity of no less than 125 percent of the AC or DC current that the circuit carries during rated conditions and in accordance with the codes in **10.2**.

10.5 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 2.0 mm². A field-wiring lead shall not be less than 150 mm long.

10.6 Field-wiring compartments in which branch circuit connections are to be made shall:

- a) Permit the connection of the supply wires after the energy storage system is installed;

- b) Permit the connection to be introduced and connected easily and safely; and
- c) Be located so that the connections may be readily inspected after the energy storage system is installed.

10.7 Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation. In safety critical circuits, for soldered terminations, the conductor shall be positioned or fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position.

10.8 A hole by which insulated wires pass through the system enclosure or elements providing separation within the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.

11 GENERAL ELECTRICAL SERVICE EQUIPMENT

11.1 For operator replaceable fuses, a fuse replacement marking with the fuse ratings shall be located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies. Where operator replaceable fuses with special characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of operator replaceable fuses shall also be included in the routine service manual instructions.

11.2 Exposed hazardous voltage in an energy storage system should have a lockable manual disconnect to enable lock-out-tag-out during servicing or for emergency procedures. The lockable manual disconnect shall have sufficient interrupt ratings, shall be accessible to the technician servicing the system or first responders and as close to the exposed hazardous voltage conductor as possible. If not provided directly on the system, the installation instructions shall indicate the type and ratings of the disconnect to be provided in the installation, how it is to be installed and connected in the circuit and where it is to be located in regard to the energy storage system.

Exception: A lockable disconnect is not required where it may be infeasible based upon the design of the system (for example, interspersed in the middle of a high voltage battery string, within a battery system, to segment the string into segments less than the minimum hazardous voltage).

11.3 Fuses, circuit breakers and disconnect devices shall be rated for the application including fault current ratings, suitability for disconnect under load,

etc., as applicable to the device and application in the system.

11.4 Transformers installed as part of the energy storage system shall be of the dry type or type filled with a noncombustible dielectric medium. Such transformers shall be installed in accordance with SP 30.

Exception: Oil filled transformers may be utilized if located outdoors and in accordance with the local codes or utility requirements.

11.5 Convenience receptacles provided for maintenance and servicing of the energy storage system shall be rated for outdoor use if the system is intended to be installed where the receptacle is exposed to the environment.

12 ELECTRICAL SPACINGS AND SEPARATION OF CIRCUITS

12.1 Electrical circuits within the energy storage system at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits or potential for arc flash (that is, electrical spacing on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and voltages shall be used where spacing cannot be controlled by reliable physical separation.

12.2 Electrical spacing in circuits shall have the following minimum over surface and through air spacing as outlined in Table 2 or as outlined in IS 13252 (Part 1).

Exception No. 1: Electrical spacing within components and parts of an energy storage system previously determined to comply with an appropriate safety standard for the equipment need not be evaluated.

12.3 There are no minimum spacing applicable to parts where insulating compound completely fills the casing of a compound or subassembly if the distance through the insulation, at voltages above 60 V_{dc} or above 30 V_{rms} is a minimum of 0.4 mm thick for supplementary or reinforced insulation, and passes the dielectric voltage withstand test. There is no minimum insulation thickness requirement for insulation of circuits at or below 60 V_{dc} or for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation. Materials employed as electrical insulation shall meet the requirements of 6.4.

12.4 Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacing requirements unless they are each provided with insulation acceptable for the highest voltage involved. An insulated conductor shall be reliably retained so that it cannot contact an

Table 2 Electrical Spacing
(Clause 12.2)

Part	Voltage AC RMS	Through Air	Over Surface
	V	mm	mm
Live parts and dead metal parts that are separated by functional or basic insulation.	0 - 50 ^a	1.6	1.6
	51 - 130	3.2	4.8
	131 - 300	6.4	9.5
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only - this ordinarily is a spacing resulting from supplementary insulation.	0 - 50 ^a	1.6	1.6
	51 - 13	3.2	4.8
	131 - 300	6.4	9.5
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation.	0 - 50 ^a	3.2	3.2
	51 - 130	4.8	6.4
	131 - 300	2.8	12.8
Between any uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded part other than the enclosure, or an exposed metal part (basic insulation).	301 - 600	9.5	12.7
	601 - 1000	14.0	17.8
	1001 - 1500	21.6	30
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable (basic insulation).	301 - 600	12.7	12.7
	601 - 1000	20.3	25.4
	1001 - 1500	30.5	41.9
^a) Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (that is, circuits supplied by limited power sources as defined IS 13252 (Part 1).			

uninsulated live part of a circuit operating at a different voltage.

13 INSULATION LEVELS AND PROTECTIVE GROUNDING

13.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in **13.2** through the following:

- Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation that complies with **13.3**;
- A system of double or reinforced insulation; or
- A combination of (a) and (b).

13.2 Safety Extra Low Voltage (SELV) circuits, as defined in **3.18** that are insulated from accessible conductive parts through functional insulation only are considered accessible.

13.3 Accessible non-current carrying metal parts of an energy storage system containing hazardous voltage circuits that could become live in the event of an insulation fault shall be bonded to the equipment ground terminal.

13.4 The protective grounding methods of an energy storage system shall be in accordance with SP 30 as applicable to where the system is located.

13.5 Parts of the protective grounding system shall be securely fastened and provided with metal-to-metal contact that will ensure the continuity of the grounding system (see **27**).

14 SAFETY ANALYSIS AND CONTROL SYSTEMS

14.1 Energy storage systems shall be provided with a report based on various safety analysis techniques such as, but not limited to, a Failure Modes and Effects Analysis (FMEA) that identifies critical safety components and circuits of the system. The analysis shall consider the compatibility of the parts of the energy storage system (for example, battery system, charger, inverter, etc.) with regard to safety of the overall system. The analysis shall be performed by the manufacturer of the energy storage system or the entity that integrates the components comprising the energy storage system. Guidance for analysis can be found in IEC 60812 and IEC 61025.

14.2 Electrical and electronic controls of the energy storage system that are determined to be critical for

safety shall comply with an appropriate safety standard for the control and used within their ratings. Electronics and software controls determined to be critical for safety shall be evaluated for functional safety to an appropriate Safety Integrity Level (SIL) or similar safety classification for the system as determined by the system safety analysis conducted as per **14.1**. Compliance to functional safety requirements shall be demonstrated through evaluation to the following standards as applicable to the system:

- a) IS/IEC 61058 (all parts), or
- b) IS/IEC 60730 (Part 1).

15 REMOTE CONTROLS

Energy storage systems which have the ability to be controlled remotely shall be provided with an accessible means to disconnect the system from the remote control. The remote control disconnect shall be provided either on the system or at the location mentioned in the installation manual specifying the location and type of disconnect. The use of a remote control systems shall not lead to an unsafe condition as determined by the system safety analysis and shall not be able to override local safety controls. If the remote control disconnect is to be provided as part of the installation (not built into the energy storage system), the instructions shall include information on the electrical connections including means to prevent disconnection from being overridden by the remote control system.

16 COMMUNICATION SYSTEMS

Instructions for installation and operation of the energy storage system shall identify the communication protocols used by the energy storage system for communication between external systems intended to be connected to the energy storage system.

17 HEATING AND COOLING SYSTEMS

Energy storage systems that rely upon integral thermal management systems to prevent overheating or operation outside the specified safe operating range of the energy storage technology shall be designed to safely shutdown upon failure of the thermal management system unless it can be demonstrated, that the thermal management system failure does not result in a hazardous situation.

18 CONTAINMENT OF MOVING PARTS

Energy storage systems having moving parts with the capacity to store kinetic energy shall be provided with a means to contain the parts in the event. They could become loosened during operation or through the influence of external forces. If it is possible for moving parts to become dislodged upon breakage or damage to their securement means, the containment

mechanism shall adequately contain the loosened parts to prevent hazards to persons or the surrounding built environment.

19 HAZARDOUS FLUID CONTAINMENT

19.1 Where the system design is such that there is a potential for spills of hazardous liquids, provisions for containment and/or neutralization of those liquids shall be provided. Methods utilized for containment shall be sufficient to hold the maximum anticipated quantity of liquid that could occur and designed to prevent inadvertent filling with rain if located outdoors. Instructions regarding the provision of suitable spill containment and neutralization shall be provided by the system manufacturer with the installation instructions, if required containment and/or neutralization is not provided as part of the energy storage system. Where flammable liquids are contained, provision for applicable fire detection and protection systems should be provided as per **21**. Automatic leak detection to indicate the release of a hazardous/flammable liquid shall be provided.

19.2 Energy storage systems that contain fluids shall be designed to prevent venting of toxic vapors in concentrations considered to be hazardous based on an evaluation conducted in accordance with **31** and **32**.

19.3 Where multi-battery energy storage systems use conductive fluids that may come in contact hazardous voltages, containment shall be provided separately for each battery.

20 COMBUSTIBLE CONCENTRATIONS

20.1 Enclosures of energy storage batteries that vent hydrogen to the atmosphere shall be ventilated to prevent hazardous concentrations of flammable materials unless equipment located within the classified area/zone within the enclosure is suitable for the classification area/zone. Concentration in nonhazardous zones of the energy storage system shall be limited to 25 percent Lower Flammability Limit (LFL) under normal maximum operating conditions. Mechanical ventilation relied upon to maintain concentrations below the required limits shall be interlocked, so that the system shuts down upon failure of the ventilation system.

Exception: Vented battery systems such as lead acid or nickel that are provided with mechanical ventilation in accordance with **20.2**, need not comply.

20.2 For battery and similar systems, openings to prevent hazardous concentrations of flammable gases within an enclosure can be used. Openings in the enclosure provided for ventilation shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen

gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25 percent of the LFL of hydrogen (equivalent to 1 percent concentration in a volume of air).

20.3 As an alternative to **20.2**, ventilation openings shall have a minimum opening area of:

$$A = 0.005NC_5 \text{ (cm}^2\text{)}$$

Where,

A = Total cross sectional net free area of ventilation openings required (cm²);

N = Number of cells in battery; and

C₅ = Capacity of battery at the 5-h rate (Ah).

Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25 percent of the LFL of hydrogen.

20.4 Electrical compartments adjacent to classified zones within the energy storage system enclosure shall be maintained at positive pressure in accordance with the IEC 60079 (Part 2).

21 FIRE DETECTION AND SUPPRESSION

21.1 The level and type of fire detection and suppression required for an energy storage system is dependent upon the size, technology and location of installation as well as the local building and fire codes or utility requirements. The fire detection and suppression system shall be built into the energy storage system's enclosure as determined from the fire risk analysis. Also, as a result of these various factors, small energy storage systems such as single package residential systems located in accordance with local residential and fire codes, may only need to be provided with instructions regarding the appropriate fire extinguishing materials to maintain within the location and housekeeping and safety procedures to follow.

21.2 To determine the level and type of fire detection and fire suppression systems required, an analysis such as a fire risk assessment with consideration to the applicable building and fire code requirements for the installation site, and other appropriate design and installation standards, shall be conducted for energy storage system installations to ensure that suitable fire prevention and fire protection requirements for protecting persons and property are met. Guidance on fire risk analysis can be found in SP 7.

21.3 Energy storage system installations required to be provided with fire suppression shall be provided with a means for fire detection and suppression in accordance with the siting of the system (that is, indoors, etc.), the energy storage technology and the applicable

installation, building and fire safety codes. If not provided as part of the energy storage system, guidance based on scientific data shall be provided for choosing, installing, operating and maintaining suitable fire detection and suppression systems in the installation, operation and maintenance instructions for the energy storage system.

22 UTILITY GRID INTERACTION

22.1 General

22.1.1 Energy storage systems under rid so as to export energy to the Electric Power Systems (EPS)/electric utility. These products fall into several groups; utility-interactive inverters, grid support utility-interactive inverters, or special purpose utility-interactive inverters.

22.1.2 Energy storage system inverters rated for connection and operation with an EPS shall be evaluated for the intended purpose as specified in this section. 'This section does not require compliance with a specific grid interconnection standard, but does require that the system operate safely over the manufacturer's specified range of grid interconnection operation including utility transient response ratings, such as Zero Voltage Ride Through (ZVRT), Low Voltage Ride Through (LVRT), High Voltage Ride Through (HVRT) or other defined limits of operation. This shall be verified by operating the system of energy storage system inverters or its subassemblies under operating parameters including the minimum and maximum voltage, frequency, and duration limits of the manufacturer's specified range of operation.

22.1.3 The inverter shall also be designed to properly interconnect with the particular energy storage technology it is connected to as determined by the system's safety analysis.

22.1.4 Products that rely upon internal or external utility interconnection protection functions or devices shall be specifically identified for the particular product. External utility interconnection protection may be required by means of utility protection relays as defined by specific product ratings and instructions.

22.1.5 It is intended that the acceptability of grid support utility interactive inverters shall be determined by the local electric utility.

22.2 Utility Grid Interactive Inverter

22.2.1 A utility-interactive inverter, grid support utility-interactive inverters, or subassembly of an energy storage system shall comply with the UL 1741, or IEC 62019 in case of electricity generation from solar photovoltaic system. These utility-interactive products may also include additional special purpose

utility-interactive features and/or functions that may be enabled in accordance with local utility interconnection protection requirements.

22.2.2 The utility-interactive inverters or converters may also include additional grid support and or special purpose utility-interactive features and/or functions that may be enabled in accordance with local utility interconnection protection requirements.

22.2.3 Grid support utility-interactive inverters or converters may also include additional grid support utility-interactive functions addressed through other standards, and other functions that may be enabled in accordance with local utility SRD(s). IEEE 1547 A and IEEE 1547.1 A allow for grid support functionality.

22.2.4 Energy storage system inverters that are rated for and or specify compliance with other specific electric utility interconnection document(s) or standard(s) shall be evaluated for compliance with the specified document(s) or standard(s).

22.3 Special Purpose Utility-Interactive Energy Storage System Inverters

22.3.1 Special purpose utility-interactive energy storage system inverters shall comply with all of the standard for inverters, converters, controllers and interconnection system equipment for use with distributed energy resources, UL 1741 construction requirements defined for utility-interactive products.

22.3.2 Special purpose utility-interactive products are intended for use in specific power production applications that export power to the electric utility. These units are often installed in power farm applications. These units may be evaluated for compliance to a subset of IEEE 1547 and IEEE 1547.1 requirements and they may also include additional special purpose utility-interactive features addressed through other standards, and other functions that may be enabled in accordance with local utility interconnection protection requirements. Special purpose utility-interactive energy storage system inverters shall comply with UL 1741 construction requirements defined for utility-interactive products.

22.3.3 Special purpose utility-interactive energy storage system inverters are only required to be evaluated for compliance with the requirements in the IEEE 1547 and IEEE 1547.1 that are supported by the system's ratings and markings.

22.3.4 Special purpose utility-interactive energy storage system inverters shall be evaluated for compliance with specific documents or requirements (in addition to the IEEE 1547 and IEEE 1547.1) only if those specific documents or requirements are referenced in the product ratings.

23 ENERGY STORAGE SYSTEM TECHNOLOGIES

23.1 Electrochemical Energy Storage Systems

Batteries, electrochemical capacitors, hybrid battery-capacitor systems or flow batteries used in an electrochemical energy storage system shall comply with the requirements of UL 1973. Testing and evaluation of the battery system, which would include the battery and its battery management system is conducted as part of evaluation to UL 1973. Inverters and charging equipment that are part of the energy storage system shall be designed for use with the battery system employed in the energy storage system. For general information on battery safety, *see* also informative Annex C.

23.2 Chemical Energy Storage Systems

23.2.1 A chemical energy storage system consists of storage of hydrogen fuel and the means to change the fuel into electrical energy using a fuel cell system or a hydrogen generator. To convert electrical energy into hydrogen fuel, a hydrogen generator using water electrolysis is also part of the overall system. Fuel cell systems that are part of a chemical energy storage system shall comply with IEC 62282-3-100.

23.2.2 For example Water electrolysis type hydrogen generators used in an energy storage system to provide hydrogen for storage shall be evaluated and found to be in compliance to an appropriate safety standard for the equipment.

23.2.3 Hydrogen fuel containing parts of a chemical energy storage system shall be constructed of materials suitable for gaseous hydrogen service at the pressures and temperatures of use.

23.3 Mechanical Energy Storage Systems

23.3.1 Mechanical energy storage systems such as, but not limited to, flywheel systems or Compressed Air Energy Storage (CAES) systems shall be evaluated to determine that hazards associated with moving parts with the capacity to store kinetic energy, and high pressure and high temperature fluids contained in the system are mitigated. Compliance is determined by evaluation to the requirements of this standard.

23.3.2 Flywheel systems and other systems with moving parts with the capacity to store kinetic energy shall comply with **30** and **32**. Parts containing hazardous fluids shall comply with **31** and **32**.

23.4 Thermal Energy Storage Systems

Thermal energy storage systems shall be evaluated to determine hazards associated with containment of high temperature and high pressure and potentially hazardous fluids are mitigated. Compliance is

determined by evaluation to the requirements of this standard. Parts containing hazardous fluids and fluids at high temperatures and pressures shall comply with 31 and 32.

24 PERFORMANCE

24.1 General

The energy storage technologies employed as part of an energy storage system shall be tested and determined compliant to an applicable technology safety standard. Where no applicable safety standard exists, they shall be tested in accordance with this standard.

24.2 All tests conducted in accordance with this standard shall be conducted in an environment with an ambient temperature of $35 \pm 5^\circ\text{C}$ unless otherwise noted in the test method. Any cooling systems or other auxiliary systems that are part of the energy storage system shall be operating during testing when their operation can affect the outcome of the test or when otherwise noted in the test method. For testing purposes, samples and parameters used for testing shall consider smallest size conductors and maximum allowed overcurrent protection in addition to worst case loading and temperatures conditions.

24.3 Temperatures shall be measured using thermocouples consisting of wires not larger than 0.21 mm^2 and not smaller than 0.05 mm^2 connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured. For those tests that require the sample to reach thermal equilibrium (also referred to as steady state conditions). Thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10 percent of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than $\pm 2^\circ\text{C}$.

24.4 The tests contained in this standard may result in explosions, fire and emissions of flammable and/or toxic fumes as well as electric shock. It is important that personnel use extreme caution and follow local and regional worker safety regulations when conducting any of these tests and that they be protected from flying fragments, explosive force, and sudden release of heat and noise that could result from testing. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases. As an additional precaution, the temperatures on surfaces of parts that may get hot or cold during testing may be monitored during the test for safety and information purposes. All personnel involved in the testing shall be instructed to never approach the Device under Test (DUT) until temperatures have returned to within ambient temperatures.

25 NORMAL OPERATIONS TEST

25.1 A normal operations test can be waived for those energy storage systems where a similar evaluation such as a temperature test has already been conducted under the specific technology standard.

25.2 In conducting the electrical tests required in this standard, the energy storage system shall be operated through a minimum of 2 cycles of charge and discharge of the system at the maximum loading rates as specified by the manufacturer. During the test, consideration shall be given to maximum and minimum ambient conditions. During operation, temperatures on critical components that are temperature sensitive shall be monitored and operating parameters of components of the system monitored to determine that they are operating within their ratings.

25.3 During the normal operations test, the manufacturer's specified limits shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications in accordance with Table 3. Temperatures on accessible surfaces of the energy storage system shall not exceed the limits in accordance with Table 4.

Table 3 Temperatures on Components

(Clause 25.3)

Part	Maximum Temperatures on Components (Tmax) °C
Synthetic rubber or PVC insulation of internal and external wiring	
— without temperature marking	75
— with temperature marking	Temperature marking
Components, insulation and thermoplastic materials	a)
Cell/capacitor casings	b)
a) The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.	
b) The internal battery cell or capacitor case temperature shall not exceed the manufacturer's recommended maximum temperature.	

Table 4 Temperatures on Accessible Surfaces

(Clause 25.3)

Accessible Surfaces	Maximum Surface Temperatures		
	Metal °C	Glass, Porcelain and Vitreous Materials °C	Plastic and Rubber ^{a)} °C
External surfaces of equipment which may be touched ^{b)}	70	80	95
Parts inside equipment which may be touched ^{c)}	70	80	95
^{a)} For each material, account shall be taken of the data from that material to determine the appropriate maximum temperature.			
^{b)} For areas on the external surface of equipment and having no dimension exceeding 50 mm (2.0 in), and which are not likely to be touched in normal use, temperatures up to 100°C are permitted.			
^{c)} Temperatures exceeding the limits are permitted provided that the following conditions are met: 1) Unintentional contact with such a part is unlikely such as equipment located in restricted access locations or due to its location; 2) The part has a marking indicating that this part is hot. It is permitted to use the symbol IEC 60417 Database, No. 5041 to provide this information.			

26 DIELECTRIC VOLTAGE WITHSTAND TEST

26.1 The dielectric voltage withstand test is an evaluation of the electrical spacings and insulation associated with the hazardous voltage circuits within the DUT.

26.2 Circuits at 42.4 V_{peak}/ 30 V_{rms} or 60 V_{dc} or higher shall be subjected to a dielectric withstand voltage in accordance with IS 13252 (Part 1).

Exception No. 1: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.

Exception No. 2: The dielectric voltage withstand test need not be conducted on integral electric energy storage systems, fuel cells, and inverter systems, etc. that have already been evaluated in accordance with their individual standard requirements. Only those electrical parts external to the tested systems and their connections not previously evaluated need to be tested.

26.3 The voltage applied during the dielectric voltage withstand test is to be applied between the hazardous voltage circuits of the DUT and non-current carrying conductive parts that may be accessible.

26.4 The voltage applied during the dielectric voltage withstand test is also to be applied between the hazardous voltage charging circuit and the enclosure/ accessible non-current carrying conductive parts of the DUT.

26.5 The voltages applied during the dielectric voltage withstand test shall be applied for a minimum of 1 min.

26.6 The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage,

which is variable and which is essentially sinusoidal if using ac test method, a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it may not be indicative of insulation breakdown.

Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

26.7 There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacing) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as dielectric breakdown (that is, insulation breakdown).

27 IMPULSE TEST

27.1 The impulse voltage test is intended to evaluate the energy storage system's ability to withstand lightning or similar surges. Systems provided with protection that has already been evaluated for voltage surges (for example, IEEE 1547 criteria) need not be tested.

27.2 The impulse voltage test shall be performed with an impulse generator able to provide voltage having a 1.2/50 µs waveform with an output impedance not exceeding 2 Ω at voltages in accordance with Table 5 and is intended to simulate an overvoltage condition due to lightning or switching of equipment.

Table 5 Impulse Voltages
(Clause 27.2)

Voltage of Circuit Under Test	Impulse Test Voltage, Voltage Between Circuits and Accessible Parts			
	Circuits Connected to Mains		Circuits Not Connected to Mains	
	Basic or Supplementary Insulation	Reinforced Insulation	Basic or Supplementary	Reinforced Insulation
V	V	V	V	V
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000
300	2 500	4 000	4 000	6 000
500	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
> 1 000	a	a	a	a

^{a)} Interpolation is permitted for circuits above 1 000 V.

27.3 Pulses shall be applied at 1.2/50 μ s for each polarity in ≥ 1 s time intervals at the peak voltage for the rating of the circuit under test ± 5 percent per Table 5. The test voltage is to be applied between the terminal/circuit under test and accessible parts. For circuits at 1 000 V or less, three pulses at each polarity shall be applied. For circuits over 1 000 V, 5 pulses at each polarity shall be applied.

27.4 As a result of the applied impulse voltage test, there shall be no puncture of insulation (that is, electrical breakdown through solid insulation), occurrence of flashover (that is, electrical breakdown over the surfaces of solid insulation), or spark-over (that is, electrical breakdown through fluids such as air).

28 EQUIPMENT GROUNDING AND BONDING TEST

28.1 The impedance of the system grounding and bonding circuit shall be determined using one of the following methods:

- The circuit between the grounding terminal and the part to be grounded is measured using impedance measuring equipment;
- In accordance with the SP30; and
- In accordance with clause **2.6.3.4** of IS 13252 (Part 1) (measuring voltage drop in circuit using a low voltage supply source providing a current based upon circuit protection rating).

28.2 The impedance for all grounding and bonding circuits tested shall not exceed 0.1 Ω .

29 INSULATION RESISTANCE TEST

29.1 The resistance of insulation used on hazardous voltage circuits within an energy storage system shall be greater than or equal to 1 M Ω .

29.2 The insulation resistance shall be measured using high impedance measuring equipment (for example, mega ohmmeter) after applying a voltage of 500 V_{dc} between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.

Exception: Energy storage systems need not be tested if the insulation resistance has been previously evaluated as part of the particular technology safety standard.

30 CONTAINMENT OF MOVING PARTS

30.1 Over Speed Qualification Test

30.1.1 An energy storage system with moving parts having the capacity to store kinetic energy that is capable of being subjected to over speed conditions through a fault in the system controls shall be subjected to an over speed test.

30.1.2 The system controls shall be subjected to a single fault in the controls that would allow over speed of the moving parts. The DUT shall be operated at over speed conditions until a secondary protection control operates to stop operation of the DUT.

30.1.3 As a result of the over speed condition, the moving part(s) shall not become loosened or disconnected in a manner that would result in a hazardous condition. If any moving part(s) get(s) completely loosened or disconnected as a result of the over speed conditions, the containment means shall safely contain the part(s) in accordance with the Faulted Securement Qualification Test in **30.2**.

30.2 Faulted Securement Qualification Test

30.2.1 An energy storage system with moving parts having the capacity to store kinetic energy shall be subjected to the faulted securement test when a fault

in primary securement means of the moving part may result in a hazard.

30.2.2 The moving parts of the system shall be subjected to a single fault of the primary means of securement, and then shall be operated at maximum normal operation. The primary means of securement to be removed, such as a failed bearing, shaft, or other part of the securement of the moving part with respect to the stationary housing, shall be determined through a safety analysis that identifies failure of the selected means as representing the potential worst case condition.

30.2.3 The system shall be operated until one of the following occurs:

- a) The part has operated for 30 min under the faulted condition;
- b) A protection control operates to stop operation of the DUT or hazardous moving part; or
- c) The part has loosened and is completely or partially disconnected from its securement means.

30.2.4 As a result of the operation with a faulted securement condition, the moving part (s) shall not become loosened or disconnected to result in a hazardous condition. If completely loosened or disconnected, the containment means for the part shall safely contain the part(s).

31 LEAKAGE TESTS

31.1 Energy storage systems that contain hazardous fluids shall be subjected to the leakage test in accordance with **31.2** and **31.3**.

Exception: Leakage testing need not be conducted if parts containing hazardous fluids and their connections have already been evaluated for external leakage as part of a component standard such as Annex C of UL 1973 or IEC 62283 -3-100.

31.2 Leakage from energy storage systems containing hazardous fluids shall not result in the risk of fire, electric shock, or injury to persons.

31.3 Compliance is determined by subjecting the fluid-containing parts and their connections to a fluid pressure of 1.5 times the maximum pressure (if testing with liquid) or 1.1 times the maximum pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks from fluid-containing parts or their connections as a result.

32 STRENGTH TESTS

32.1 General

Energy storage systems that contain hazardous fluids shall comply with the strength tests in accordance with **32.2** and **32.3**.

32.2 Hydraulic Strength Test

32.2.1 Parts of energy storage system containing hazardous fluid (gases or liquids) shall be tested for hydrostatic strength under the following conditions:

Test pressure for hydrostatic pressure = 1.5 times design pressure.

Duration for maximum applied pressure = 1 min.

Liquid used for testing = Either the liquid used in system or water

Test temperature = Ambient temperature

Duration of gradual increase in pressure to reach test pressure = 1 min.

32.2.2 As a result of the hydrostatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.

32.3 Pneumatic Strength Test

32.3.1 The pneumatic strength test is an alternative to the hydrostatic strength test of **30.2** and is conducted in accordance with **32.3.2**.

32.3.2 Parts of the energy storage system containing hazardous fluids (gases or liquids) shall be tested for Pneumatic Strength under the following conditions:

Test pressure for pneumatic strength test = 1.3 times design pressure.

Duration for maximum applied pressure = 1 min.

Liquid used for testing = Either air or inert gas.

Test Temperature = Ambient temperature.

Duration of gradual increase in pressure to reach test pressure = 1 min.

32.3.3 As a result of the pneumatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.

33 SPECIAL ENVIRONMENT INSTALLATIONS

33.1 General

Energy storage systems intended for installation in special environments shall be evaluated for their ability to operate safely in those environments. These environmental conditions can include exposure to salt fog for marine environments, testing for seismic ratings, high altitudes, etc. depending upon the particular special exposure. Environmental standards such as the IEC 60068 series shall be used to determine compliance. The installation instructions and nameplate labels on the energy storage system shall identify the special environmental conditions in accordance with **37.3**, **37.8**, and **38**.

Exception: Test need not be conducted on systems or parts of the system if already covered as part of the specific technology safety standard.

33.2 Outdoors Installations Subject to Moisture Exposure

33.2.1 Energy storage systems installed outdoors are subjected to rated levels of moisture exposure therefore shall be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions of **37.8** and **38.4**.

33.2.2 Based upon the ratings of the system, moisture resistance testing shall be done in accordance with IS/ IEC 60529.

33.2.3 At the conclusion of the test, the sample is to be subjected to the electric insulation tests of **26** and **29** and examined for signs of water in the system that could result in a hazardous condition.

33.2.4 As a result of the water exposure, there shall be no evidence of water on parts that could result in a hazard and no reduction of spacing or breakdown/deterioration in insulation levels.

33.3 Outdoor Installation Near Marine Environments

33.3.1 Energy Storage Systems installed outdoors near marine environments in accordance with **38.6** where they are subjected to salt fog exposure, shall be tested as follows.

33.3.2 The systems shall be tested in accordance with IEC 60068-2-52.

33.3.3 At the conclusion of the testing, the systems shall be subjected to the electrical insulation tests of **27** and **29** to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.

33.3.4 The system shall be examined for signs of damage as a result of salt exposure that would indicate a potential for a safety hazard (for example, corrosion of parts that could result in weakening of a securement or an enclosure, damage to insulation). If operational, the system is to be operated to determine that it can do so without hazard.

33.3.5 As a result of the test, the energy storage system shall not show evidence of damage from salt fog exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.

33.4 Installation in Seismic Environments

33.4.1 Energy storage systems intended for installation where they will be subject to seismic activity shall be evaluated and if necessary tested in accordance with their seismic ratings and installations instructions as per **37.3** and **38.6**. The installation instructions shall

indicate the limitations of the particular seismic rating of the equipment. The guidance on seismic evaluation can be taken from IEEE 693 or IEC 60980.

33.4.2 The energy storage system shall be examined for signs of explosion, fire, combustible concentrations (if applicable to technology), rupture of the enclosure, electrolyte leakage, electric shock and loss of protection controls that may lead to any of the other non-compliant results in **33.4.3**.

33.4.3 As a result of the test, any of the following results in (a) to (g) are considered a non-compliant result:

- a) Explosion;
- b) Fire;
- c) Combustible concentrations (if applicable to technology);
- d) Rupture (enclosure);
- e) Electrolyte leakage (external to enclosure);
- f) Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); and
- g) Loss of protection controls.

34 DIELECTRIC VOLTAGE WITHSTAND TEST

A dielectric withstand test as outlined in the dielectric voltage withstand test in **26** shall be conducted on 100 percent production of energy storage systems with working voltage exceeding $60 V_{dc}$ or $30 V_{rms}/42.4 V_{peak}$.

Exception No. 1: The time for the production dielectric withstand test can be reduced to 1 s.

Exception No. 2: Testing can be conducted on subassemblies of the system.

Exception No. 3: Testing can be waived if conducted as part of the specific technology evaluation (that is, tested as per UL 1973, etc.).

35 GROUNDING AND BONDING SYSTEM CHECK

35.1 The grounding and bonding system of an energy storage system shall be subjected to a check using an impedance measuring device. The measurements shall occur between any two locations of the grounding and bonding system.

35.2 No resistance measurements of the grounding and bonding system shall exceed 0.1Ω .

36 MAXIMUM ABNORMAL OPERATING SPEED

Every production mechanical storage element shall be subjected to a maximum abnormal operating speed test. The test shall be performed at the maximum speed reached during the over speed qualification test of

30.1. The test shall be performed in an environment which will safely contain any mechanical failure of the mechanical storage element.

37 MARKINGS

37.1 General

The markings including signage required for compliance to this standard shall be legible and permanent such as metal stamped, etched, adhesive labels, etc. A mark can be embossed or silk screened on any colored material or printed with the same color used for rating labels or carton box markings. Compliance is checked by inspection and by rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit. After all the tests specified in the standards, the marking shall be clearly legible, it shall not be easily possible to remove marking plates and they shall show no curling.

NOTE — the petroleum spirit to be used for the test is aliphatic solvent hexane having a maximum aromatics content of 0.1 percent by volume, a kauri-butanol value of 29, an initial boiling point of approximately 65 EC, a dry point of approximately 69EC and a specific mass of approximately 0.66 kg/l.

An adhesive-backed label shall comply with the requirements as below.

37.2 Markings and signage shall be in lettering that is sized so that it is legible from the distance from which it must be read and shall have lettering in a color that contrasts with the background. Guidance for markings and signs can be found in ISO 3864-2 and IEC 60417.

37.3 Energy storage systems shall be marked with the manufacturer's name, trade name, trademark or other descriptive marking which identifies the organization responsible for the product, part number or model number, and electrical ratings and other ratings in (a) to (m). All ratings and rating information necessary for the installation and operation of the energy storage system shall be provided in the system instructions. If the installation location of the system has limitations (that is, can only be located indoors where it is sheltered from rain and UV or outdoors only), these location limitations shall be indicated on the label and installation instructions. If the system is intended for installation in a location where local regulations indicate a need for a seismic rating on equipment, an appropriate seismic rating shall be included on the label.

- a) Output and input current (maximum), in Amps;
- b) Output and input voltage (maximum), in Volts;
- c) Power input and output (maximum), in Watts;

Test	Requirement
Defacement Test	
Labels or unprinted materials are to be scraped back and forth ten times across printed areas and edges, with a downward force of between 7.2 and 9 N using the edge of a 1.65mm to 2.54mm thick steel blade held at a right angle to the test surface. The portion of the blade contacting the test surface shall have a radius of curvature of 25.4 to 33.0 mm and the edges of the blade shall be rounded to a radius of 0.41 ± 0.08 mm. ^{a),b)}	A label or unprinted material, including over-lamination or overprint coating, if present, shall remain in place and shall not be torn, uplifted, or otherwise damaged. Scratching or defacement of unprotected printing, either text or background, is not considered a non-compliance.
Adhesion Test: Test strips approximately 12.7 mm wide are to be prepared by making two parallel cuts through the sample to the test surface, using a sharp instrument such as a razor blade. Strips are to be cut parallel to the length and width of the sample if the size and configuration of samples allows. One end of each strip shall be separated from the surface for attachment to the apparatus for test. The remainder of each strip, at least 25.4 mm is then to be pulled from the surface at a 90 ± 5 degree angle and at a rate of 50.8 ± 2.5 mm/min, using a tension machine equipped with an automatic recorder that graphs the adhesion profile of the test strip. The average force required to remove the strip is to be calculated in N/mm width rounding to the nearest 0.002 N/mm. The value obtained for two or more samples is to be averaged and taken as the quantitative adhesion value. Notation shall be made if the quantitative adhesion value drops below 0.02 N/mm at any point during the test.	
This test is to be conducted if it is possible to remove test strips from surfaces. If removal is not possible because of breaking, tearing, or excessive rigidity of the label material, adhesion is to be determined by attempting to remove the entire sample by hand. ^{c)}	The average quantitative adhesion value shall not be less than 0.088 N/mm width and the adhesion shall not be less than 0.0175 N/mm at any point. If it is not possible to separate test strips from the surface, the sample shall show good adhesion to the surface when removal by hand is attempted.
^{a)} The back of the blade of a pocket knife conforming to the description indicated has been found suitable for performing this test. Other devices conforming to the description indicated may be used.	
^{b)} Labels intended to be mechanically affixed shall be evaluated by holding the label on a flat test surface for support.	
^{c)} The adhesion test is not applicable to labels intended to be mechanically affixed.	

- d) Energy output in Wh (maximum);
- e) Auxiliary output and input voltage (V), current (A) and frequency (Hz) if applicable;
- f) Number of phases (for input and output);
- g) Frequency, in Hz;
- h) Duty cycle (if applicable);
- j) Maximum short circuit current, in Amps;
- k) Ambient temperature range, in °C;
- m) Special environmental ratings and limitations as applicable (for example, seismic, indoor/outdoor only, etc.);
- n) Weight (maximum), in kg; and
- p) Maximum dimensions for height, width, and length (this dimensions information need not be marked on the system as long as it is provided in the installation instructions).

37.4 Energy storage systems shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 20 years. All external terminals and connections shall be provided with identification.

37.5 The point of connection to the charger earth grounding system shall be identified by the word 'Ground' or the letters 'G' or 'GR' or the grounding symbol as defined in IEC 60417 (upside down tree within a circle) or otherwise identified by a distinctive green color. Any other grounding terminals shall also be identified in a manner that is distinctive from the main earth ground terminal for the charger system.

37.6 The energy storage system that contains hazardous voltage circuits shall be marked 'WARNING: Hazardous Voltage Circuits' or be marked with the electric shock hazard symbol as per ISO 3864 (Part 2) No. 5036 (lightning bolt within a triangle). Electrical equipment parts of the energy storage systems such as control panels and the enclosures of disconnecting devices are also to be marked with arc flash markings according to the SP 30 and arc flash personal protective equipment (PPE) requirements, to warn service personnel of potential for arc flash hazards and necessary protection to be worn if applicable.

37.7 Energy storage systems shall be marked as follows: 'WARNING: To Reduce the Risk of Injury, read all instructions' or marked with the symbols W001 (that is, exclamation point in triangle) and M002 of ISO 7010 (Part 2).

37.8 An energy storage system intended for installation where it may be exposed to moisture shall be marked with the environmental rating of its enclosure (that is, IPX2, Type 4X, etc.) suitable for that type of exposure. See 33.2.

37.9 The control devices and indicators required for operation or maintenance shall be marked with their function on or adjacent to the control.

38 GENERAL

38.1 The energy storage system shall be provided with complete instructions for installation, operation and maintenance of the system in accordance with the technical documentation section, as per Annex D. Instructions for installation, operation and maintenance of the energy storage system shall address electrical safety including arc flash in accordance with the standard for electrical safety in the workplace.

38.2 All cautionary markings and ratings provided on the system, as well as system specifications needed for installation and operation of the system, shall be included in the instructions.

38.3 Energy storage systems shall be provided with complete instructions for installation. The installation instructions shall include all information necessary for commissioning of the energy storage system. The installation information shall include instructions for making all necessary connections for electrical, communications, piping for fuels and other fluids, etc. as well as connections to other equipment that may be part of the system. The instructions shall include information on electrical disconnects, shut off valves and other devices required to be installed with the system. The installation instructions shall include the parameters required for electrical connections and installed devices in electrical circuits (communication protocols, circuits and devices) as well as parameters for fuel and other fluid connections and control devices necessary for the operation of the energy storage system.

38.4 With reference to 37.3, the installations instructions shall specify that the system be installed in accordance with local electrical, building, fire and other codes or utility requirements as applicable to the installation and equipment, by qualified service personnel in accordance with the installation instructions and appropriate practices. Systems intended for installation in restricted access locations per 3.15 shall be designated by the manufacture if they are to be considered under this standard. If restricted access locations are identified by the manufacturer, the training required to gain access shall also be identified by the manufacturer including information in the installation, operation and maintenance instructions. The specific application location information such as the system being intended for utility premise installations or residential and commercial installations, etc. shall be identified in the installation instructions, if the system limited to installation only in those locations.

38.5 With reference to **37.3**, the installation instructions for energy storage systems containing large amounts of free electrolyte such as flow batteries or lead acid types, etc. shall be provided with instructions for location of eye wash stations. In addition, if necessary in accordance with building codes, installation instructions shall provide information on spill containment to be installed with the system as per **19.1**.

38.6 Energy storage systems intended for installation only in certain environments such as indoors only or where exposed to moisture, seismic activity or near marine environments, or to be installed in restricted access locations, shall indicate this in the installation instructions. Systems intended for exposure to moisture, marine environments or seismic activity per installation instructions shall be evaluated as per **32**.

38.7 The installation instruction shall include any special handling and safeguard measures to be followed during installation and shall include details of support structures such as concrete pads, etc. required for installation at the site.

38.8 The operating instructions shall contain instructions for decommissioning and disposing of the energy storage system at the end of life of the system. Instructions shall also include provisions of recycling or repurposing, if possible.

38.9 An energy storage system shall be provided with instructions for the proper operation of the system including charging and discharging for battery systems, and operation of system controls. The

operating instructions shall include safety measures and applicable safety warnings for operation and any instructions necessary for emergency procedures.

38.10 The energy storage system shall be provided with maintenance instructions for service personnel as well as a separate set of instructions for any basic maintenance procedures that would be handled by operators of the system. Maintenance instructions shall include frequency of routine maintenance to be performed including annual checks on any subsystems such as HVAC, Fire Suppression System, etc., as well as operational tests to be performed. The maintenance instructions shall include safety measures to be followed during maintenance of the system whether by service personnel or for basic maintenance procedures handled by system operators.

38.11 The maintenance instructions shall be provided with information on field replacement of replaceable materials, components and parts for ongoing maintenance and repair of the system. These instructions shall include detailed information on where to obtain and how to install the replaceable items. The instructions shall indicate that all servicing and replacement of parts are to be done by qualified persons only and that only approved materials, components and parts are to be used for replacements.

38.12 The installation instructions shall contain all energy storage system operation mode/settings, operation function/settings and protection/settings, which the inverters can provide.

ANNEX A

(Clause 2)

<i>IS No./Other Publications</i>	<i>Standard Title</i>
SP 7 : 2016	National Building Code of India
SP 30 : 2013	National Electrical Code 2011
IS 13252 (Part 1) : 2010	Information technology equipment — Safety: Part 1 General requirements
IS 13252 (Part 21) : 2013	Information technology equipment — Safety: Part 21 Remote power feeding
IS 13252(Part 22) : 2014	Information technology equipment — Safety: Part 22 Equipment to be installed outdoors
IS 14321 : 1995	Corrosion of metals and alloys — Recommended values for the corrosively categories of atmospheres
IS 16221 (Part 1) : 2016	Safety of power converters for use in photovoltaic power systems: Part 1 General requirements
IS 16221 (Part 2) : 2015	Safety of power converters for use in photovoltaic power systems: Part 2 Particular requirements for inverters
IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP Code)
IS/IEC 60730 – 1 : 1999	Automatic electrical controls for household and similar use: Part 1 General requirements
IS/IEC 61058 (all 2000 parts)	Switches for Appliances
IS/IEC 61508 (all parts)	Functional safety of electrical/electronic/programmable electronic safety-related systems
IS/IEC 61508 – 1 : 1998	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 1: General requirements
IS/IEC 61508 – 2 : 2000	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 2 Requirements for electrical/electronic/programmable electronic safety-related systems
IS/IEC 61508 – 3 : 1998	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 3 Software requirements
IS/IEC 61508 – 4 : 1998	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 4 Definitions and abbreviations
IS/IEC 61508 – 5 : 1998	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 5 Examples of methods for the determination of safety integrity levels
IS/IEC 61508 – 6 : 2000	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 6 Guidelines on the application of IEC 61508-2 and IEC 61508-3
IS/IEC 61508 – 7 : 2000	Functional safety of electrical/electronic/programmable electronic safety-related systems: Part 7 Overview of techniques and measures
IEC 60086-1 : 2015	Primary batteries — Part 1: General
IEC 60068-2-52 : 2017	Environmental testing — Part 2: Tests — Tests Kb, salt mist, cyclic (sodium chloride solution)
IEC 60417 : 2002	Graphical symbols for use on equipment
IEC 60812 : 2018	Analysis techniques for system reliability — Procedures for failure mode and effects analysis (FMEA)
IEC 60980 : 1989	Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations
IEC 61000 (all parts)	IEC 61000 series reflects Subjects dealt with by basic EMC publications

<i>IS No./Other Publications</i>	<i>Standard Title</i>
IEC 61025 : 2006	Fault tree analysis (FTA)
IEC 61429 : 1995	Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135
ISO 3864-2 : 2016	Graphical symbols — Safety colours and safety signs — Part 2: Design principles for product safety labels
ISO 7010 : 2011	Graphical aymbols — Safety colours and safety signs — Registered safety signs
ISO 12944-2 : 2017	Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments
IEEE 693 : 2018	IEEE recommended practice for seismic design of substations
IEEE 1547 : 2018	Interconnecting distributed resources with electric power systems
UL 746 C : 2018	Polymeric Materials — Use in Electrical Equipment Evaluations
UL 1741 : 2010	Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
UL 1973 : 2018	Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications
ASHRAE 62.1 : 2016	Ventilation for Acceptable Indoor Air Quality (American Society of Heating, Refrigeration and Air-Conditioning Engineers)

ANNEX B*(Informative)*

<i>Reference Standard Number</i>	<i>Standard Title</i>
IS 15549 : 2005	Stationary valve regulated lead acid batteries — Specification
IS 16046 -1 : 2018	Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications
IEC 60896-21 : 2004	Stationary lead-acid batteries — Part 21: Valve regulated types — Methods of test
IEC 60896-22 : 2004	Stationary lead-acid batteries — Part 22: Valve regulated types — Requirements
IEC 62133-1 : 2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications — Part 1: Nickel systems
IEC 62133-2 : 2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications — Part 2: Lithium systems
IEEE 1188 : 2005	Maintenance, testing, and replacement of valve-regulated lead-acid (VRLA) batteries for stationary applications
SAE J2464 /	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
SAE J2929	Electric and Hybrid Vehicle Propulsion Battery System Safety Standard — Lithium-based Rechargeable Cells

ANNEX C

(Clause 23.1 and 31.1)

GENERAL BATTERY SAFETY CONSIDERATIONS

C-1 GENERAL

The battery specific safety requirements for this standard is given in UL 1973. *See 25.1.* The following includes some general safety recommendations for cells and batteries used in electrochemical type energy storage systems.

C-2 DESIGN RECOMMENDATIONS

C-2.1 Battery systems should have two-fault tolerance for all catastrophic failures including overcharge, over discharge, short circuit and extreme temperatures.

C-2.2 The chargers used for charging the energy storage battery systems should be designed for the chemistry of the battery to be charged. The charging algorithm should be verified to ensure that the charging procedure is suitable for the battery chemistry and battery design.

C-2.3 Protection circuits should be verified by test in the relevant battery design configuration and worst case environments to confirm that they provide the required protective functions.

C-2.4 Cell level protection should not be relied upon for battery pack protection unless it can be verified through analysis and testing of the battery that the cell protection provides sufficient protection at the battery pack level.

C-2.5 For lithium ion batteries and any other chemistry as determined by the battery system safety analysis, voltage should be monitored for every series element, temperatures should be monitored throughout the battery pack, and battery level current monitoring should be carried out continuously with alarm and control circuits able to react. Thermal runaway protection should be provided. Such protection should be verified through testing that it provides sufficient protection of the battery pack. Any off-nominal values should be recorded by the Battery Management System (BMS).

C-2.6 For aqueous battery chemistries such as lead acid or nickel cadmium, battery or module level voltage, temperature and current monitoring should be carried out continuously with alarm and control circuits able to react. If possible, any off-nominal values should be recorded by the control system.

C-2.7 Consideration should be given for conducting high fidelity thermal analysis when developing battery designs to determine the appropriate locations of the thermal sensors used in the battery.

C-2.8 All temperature sensor readings should be continuously recorded and controls set in place to trigger a stoppage of charging or discharging of the battery when the temperature readings go above the manufacturer's rating of that particular cell or battery design.

C-2.9 If the battery is used only periodically, the battery should be designed to prevent cells from going into an over discharge mode due to the long term storage conditions.

C-2.10 For lithium battery designs and other technologies as determined through safety analysis, cells should be spaced or insulated from other cells appropriately or through other mechanisms to prevent cell to cell thermal runaway propagation in the event that any one cell experiences a thermal runaway event.

C-2.11 If temperature control is required for the battery system, the failure of the temperature controls, such as failure of heaters, cooling systems, or their controls, should not impose a safety hazard.

C-2.12 For systems requiring heaters for operation, heater designs should not result in temperatures that exceed specified safe operating temperatures of the batteries.

C-2.13 For systems requiring active cooling systems, a failure of the cooling system due to breach or breakage in the cooling lines should not result in a leakage that will cause short circuiting of the cells inside the battery pack leading to a hazardous condition. Coolant leakage lines should be routed or secured to mitigate the potential for leakage on live parts and if necessary fluid monitor and controls of the coolant system may need to be provided.

C-2.14 For lithium batteries and other technologies as determined by the battery safety analysis, to prevent any unforeseen hazards due to a complex design and usage environment, the thermal runaway propagation test should be performed on a subset of the battery system design. This test should be carried out to understand the worst case failure that can occur in the battery design due to single cell undergoing thermal runaway and to understand how this catastrophic event propagates to the other cells in the battery system. This test can be carried out by using a heater or other method to induce thermal runaway in a single cell and then observing surrounding cells.

C-2.15 All parameters such as cell voltages, battery voltage, battery current (sub-module currents, if applicable) and temperatures should be verified to be within the specification for the cells and battery system.

ANNEX D

(Clause 38.1)

D-1 GENERAL

D-1.1 The information necessary for installation, operation, and maintenance of the electrical energy storage system shall be supplied in the form of drawings, diagrams, charts, tables, and instructions as appropriate. For very simple equipment, the relevant information shall be permitted to be contained in one document provided this document shows all the devices of the electrical energy storage system and enables the connections to the supply network to be made.

D-1.2 The electrical energy storage system supplier shall ensure that the technical documentation specified in this chapter is provided with each electrical energy storage system.

D-1.3 Technical documentation shall be supplied in a medium agreed upon by the electrical energy storage system supplier and the user of electrical energy storage system.

D-2 INFORMATION

The following information shall be provided with the electrical equipment:

- a) Clear, comprehensive description of the equipment, installation and mounting, and the connection to the electrical supply;
- b) Electrical supply circuit(s) requirements;
- c) Overview (block) diagram(s) where appropriate;
- d) Schematic diagram(s);
- e) Information (where appropriate) on the following:
 - 1) Programming,
 - 2) Sequence of operation(s),
 - 3) Frequency of inspection
 - 4) Frequency and method of functional testing,
 - 5) Adjustment, maintenance, and repair,
 - 6) Interconnection diagram,
 - 7) Panel layouts,
 - 8) Instruction and service manuals, and
 - 9) Physical environment (for example, lighting, vibration, noise levels, atmospheric contaminants)

- f) A description (including interconnection diagrams) of the safeguards, interacting functions, and interlocking of guards with potentially hazardous motions;
- g) A description of the safeguarding means and methods provided where the primary safeguards are overridden (for example, manual programming, program verification);
- h) Information for safety lockout procedure;
- j) Explanation of unique terms;
- k) Parts list and recommended spare parts list;
- m) Maintenance instructions and adjustment procedures;
- n) Reference information (where appropriate) on the following (any applicable):
 - 1) Lubrication diagram,
 - 2) Pneumatic diagram,
 - 3) Hydraulic diagram, and
 - 4) Miscellaneous system diagrams (for example, coolant, refrigerant).

D-3 REQUIREMENTS APPLICABLE TO ALL DOCUMENTATION

D-3.1 The documents shall be prepared in accordance with the requirements of **D-2**.

D-3.2 For referencing of the different documents, the supplier shall select one of the following methods:

- a) Each of the documents shall carry as a cross-reference the document numbers of all other documents belonging to the electrical equipment. This method shall be used only where the documentation consists of four or fewer documents.
- b) All documents shall be listed with document numbers and titles in a drawing or document list.

D-3.3 Where appropriate, a table of contents shall appear prominently on the first sheet and shall refer to all major sections of the electrical drawings.

D-4 BASIC INFORMATION

The technical documentation shall be permitted to be presented as a separate document or as part of

the installation or operation documentation. The technical documentation shall contain, as a minimum, information on the following:

- a) Normal operating conditions of the electrical equipment, including the expected conditions of the electrical supply and, where appropriate, the physical environment;
- b) Handling, transportation, and storage; and
- c) Inappropriate use(s) of the equipment.

D-5 INSTALLATION DIAGRAM

D-5.1 The installation diagram shall provide all information necessary for the preliminary work of setting up the electrical energy storage system.

D-5.2 The specified position of the electrical supply to be installed on site shall be clearly indicated.

D-5.3 The data necessary for choosing the type, characteristics, rated currents, and setting of the overcurrent protective device(s) for the supply circuit conductors to the electrical energy storage system of the machine shall be stated.

D-5.4 Where necessary, the size, purpose, and location of any raceways in the foundation that are to be provided by the user shall be detailed.

D-5.5 The size, type, and purpose of raceways, cable trays, or cable supports between the machine and the associated equipment that are to be provided by the user shall be detailed.

D-5.6 Where necessary, the diagram shall indicate where space is required for the removal or servicing of the electrical equipment.

D-5.7 Where it is appropriate, an interconnection diagram or table shall be provided. That diagram or table shall give full information about all external connections. Where the electrical equipment is intended to be operated from more than one source of electrical supply, the interconnection diagram or table shall indicate the modifications or interconnections required for the use of each supply.

D-6 BLOCK (SYSTEM) DIAGRAMS AND FUNCTION DIAGRAMS

Where it is necessary to facilitate the understanding of the principles of operation, a system diagram shall be provided. A block diagram shall symbolically represent the electrical equipment together with its functional interrelationships without necessarily showing all of the interconnections.

D-7 CIRCUIT DIAGRAMS

D-7.1 Diagrams, including machine schematics, of the electrical system shall be provided and shall show the electrical circuits on the machine and its associated electrical equipment. Electrical symbols shall be in accordance with IS 10232 where included therein. Any electrical symbols not included in IS 10232 shall be separately shown and described on the diagrams. The symbols and identification of components and devices shall be consistent throughout all documents and on the machine.

NOTE — Wiring schematics shall not be required for commercially available or field replaceable components.

D-7.2 Where appropriate, a diagram showing the terminals for interface connections shall be provided. Switch symbols shall be shown on the electromechanical diagrams with all supplies turned off (e.g., electricity, air, water, lubricant) and with the system and its electrical equipment in the normal starting condition and at 35°C ambient temperature. Control settings shall be shown on the diagram.

D-7.3 Identification of Conductors

D-7.3.1 General Requirements

D-7.3.1.1 Conductors shall be identified at each termination by number, letter, color (either solid or with one or more stripes), or a combination thereof and shall correspond with the technical documentation as defined in this appendix. Internal wiring on individual devices purchased completely wired shall not require additional identification.

D-7.3.1.2 Where numbers are used to identify conductors, they shall be Arabic; letters shall be roman (either uppercase or lowercase).

D-7.3.2 Identification of the Equipment Grounding Conductor

D-7.3.2.1 The color green shall be used to identify the equipment grounding conductor where insulated or covered. This color identification shall be strictly reserved for the equipment grounding conductor.

Exception No. 1: In multi conductor cable-connected assemblies where equipment grounding is not required, the solid color green shall be permitted for other than equipment grounding.

Exception No. 2: It shall be permitted to use conductors of other colors, provided the insulation or cover is appropriately identified at all points of access.

Exception No. 3: For grounded control circuits, use of a green insulated conductor or a bare conductor from

the transformer terminal to a grounding terminal on the control panel shall be permitted.

D-7.3.2.2 Where the equipment grounding conductor is identified by its shape, position, or construction (for example, a braided conductor) or where the insulated conductor is not readily accessible, color coding throughout its length shall not be required. The ends or accessible portion shall be clearly identified by the symbol in Fig. C-7.4.2.1, the color green.



FIG. C-7.4.2.1

D-7.3.3 Identification of the Grounded Circuit Conductor

D-7.3.3.1 Where an a.c. circuit includes a grounded conductor, this conductor shall be white or gray.

Exception: Grounded conductors in multi conductor cables shall be permitted to be permanently identified at their terminations at the time of installation by a distinctive white marking or other equally effective means.

D-7.3.3.2 The use of other colors for the following applications shall be as follows:

- a) White with blue stripe for grounded (current carrying) dc circuit conductor;
- b) White with orange stripe for grounded (current carrying) ac circuit conductor, which remains energized when the main supply circuit is disconnected, means is in the off position; and
- c) Whichever color stripe is selected, that color stripe shall be consistent with the ungrounded conductor of the excepted circuit described in 5.3.5.

D-7.4 Circuit Characteristics

D-7.4.1 Circuits shall be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location.

D-7.4.2 Across-referencing scheme shall be used in conjunction with each relay, output device, limit switch, and pressure switch so that any contact associated with the device can be readily located on the diagrams.

D-7.4.3 Control circuit devices shall be shown between vertical lines that represent control power wiring. The

left vertical line shall be the control circuit's common and the right line shall be the operating coil's common. Control devices shall be shown on horizontal lines (rungs) between the vertical lines. Parallel circuits shall be shown on separate horizontal lines directly adjacent to (above or below) the original circuit.

D-7.4.4 An interconnection diagram shall be provided on large systems having a number of separate enclosures or control stations. It shall provide full information about the external connections of all of the electrical equipment on the machine.

D-7.4.5 Interlock wiring diagrams shall include devices, functions, and conductors in the circuit where used.

D-7.4.6 Plug/receptacle pin identification shall be shown on the diagram(s).

D-8 OPERATING MANUAL

D-8.1 The technical documentation shall contain an operating manual detailing proper procedures for setup and equipment use.

D-8.2 Where the operation of the equipment is programmable, detailed information on methods of programming, equipment required, program verification, and additional safety procedures (where required) shall be provided.

D-9 MAINTENANCE MANUAL

D-9.1 The technical documentation shall contain a maintenance manual detailing proper procedures for adjustment, servicing and preventive inspection, and repair.

D-9.2 Where methods for the verification of proper operation are provided (for example, software testing programs), the use of those methods shall be detailed.

D-9.3 Where service procedures requiring electrical work while equipment is energized, the technical documentation shall refer to appropriate safe work practices.

D-10 PARTS LIST

D-10.1 The parts list shall comprise, as a minimum, information necessary for ordering spare or replacement parts (for example, components, devices, software, test equipment, technical documentation) required for preventive or corrective maintenance, including those that are recommended to be carried in stock by the equipment user.

D-10.2 The parts list shall show the following for each item:

- a) Reference designation used in the documentation,
- b) Its type designation,
- c) Supplier (and supplier's part number),
- d) Its general characteristics where appropriate, and
- e) Quantity of items with the same reference designation.

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